The Sr Budget in the Croatan National Forest

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Abstract

Samples of surface waters (lakes and rivers), precipitation, surficial well water, and vegetation were collected from the region of the Croatan National Forest of North Carolina. Using mass spectrometry, Sr concentrations and $^{87}Sr/^{86}Sr$ ratios were calculated. Precipitation samples have $^{87}Sr/^{86}Sr$ ratios ranging from 0.708738 ± 0.00001 – 0.710630 ± 0.00001. The average $^{87}Sr/^{86}Sr$ ratio for precipitation samples is 0.709364. The $^{87}Sr/^{86}Sr$ ratios for surface water samples are widely variable, with a range of 0.708611 ± 0.00001 - 0.710859 ± 0.00001. Rivers and lakes in the Croatan National Forest that have not mixed with the Neuse River or Trent River have $^{87}Sr/^{86}Sr$ ratios higher than modern seawater and precipitation, indicating that when precipitation falls in the forest it mixes with a source of high $^{87}Sr/^{86}Sr$ ratios relative to seawater. The Neuse River, Trent River, and surface waters that mix with the Neuse and Trent Rivers have $^{87}Sr/^{86}Sr$ ratios within error of modern seawater. Samples from the White Oak River and the western Trent River have $^{87}Sr/^{86}Sr$ ratios within the range of $^{87}Sr/^{86}Sr$ ratios predicted on $^{87}Sr/^{86}Sr$ seawater curves for formations that are late Eocene to early Miocene in age. Samples from surficial wells have $^{87}Sr/^{86}Sr$ ratios of 0.709687 ± 0.00001 and 0.709415 ± 0.00001, within the range of surface water samples and higher than modern seawater (0.70918). We conclude that an undetermined source with high $^{87}Sr/^{86}Sr$ ratios is interacting with the Croatan National Forest region, and we hypothesize that this source may be atmospheric dust or upwelling of deep groundwater that has come in contact with basement rocks.

Introduction

A study of the pocosin of the Croatan National Forest (Sun, 2012) near the coast of North Carolina found that $^{87}Sr/^{86}Sr$ ratios of the peat are 0.711959 ± 0.000005 - 0.718209 ± 0.000005. The Croatan National Forest (CNF) rests upon the Castle Hayne, River Bend, Belgrade, and Trent formations, which are Eocene to Miocene in age (Kier, 1997), and is close in proximity to the coast of the Atlantic Ocean. The $^{87}Sr/^{86}Sr$ ratios of the peat are far above the range of values of Eocene to Miocene seawater, which is 0.7076-0.7089 (Burke et al, 1982), the groundwater in the region, which is 0.708104-0.709006 (Woods et al, 2000), and modern seawater, which is 0.70918 (Woods et al, 2000).

In order to improve understanding of the Sr budget in the Croatan National Forest region, this study examines $^{87}Sr/^{86}Sr$ ratios and Sr concentrations of surface waters (from lakes and rivers), precipitation, water from two surficial wells, and vegetation samples collected in the region.

Setting

The Croatan National Forest is located on the coast of North Carolina, near the cities of Morehead and New Bern (Figure 1). It is bordered by Bogue Sound, the Neuse River, and the White Oak River. Much of the forest lies on a pocosin, or a raised bog. Because the pocosin is higher in elevation than the areas surrounding it, it is expected that water flows radially out of the pocosin, and therefore the major input of water to the pocosin is precipitation (Figure 2).

The Croatan National Forest lies above the Mesozoic basement rocks of the Carteret batholith, which is composed of quartz monzonite, diorite, gabbro, and felsic volcanic rocks. These basement rocks are at a depth of 1500-4000 feet (457-1219 m) below sea level (Lawrence et al, 1993).

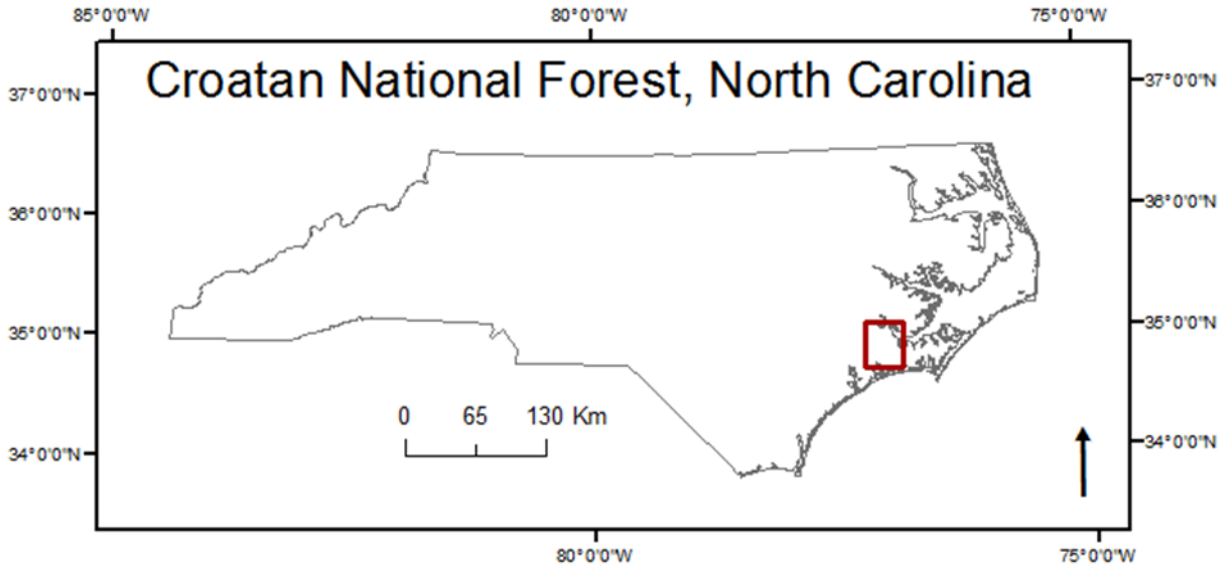

Figure 1: North Carolina. The Croatan National Forest region, which is the subject of this study, is highlighted in red.

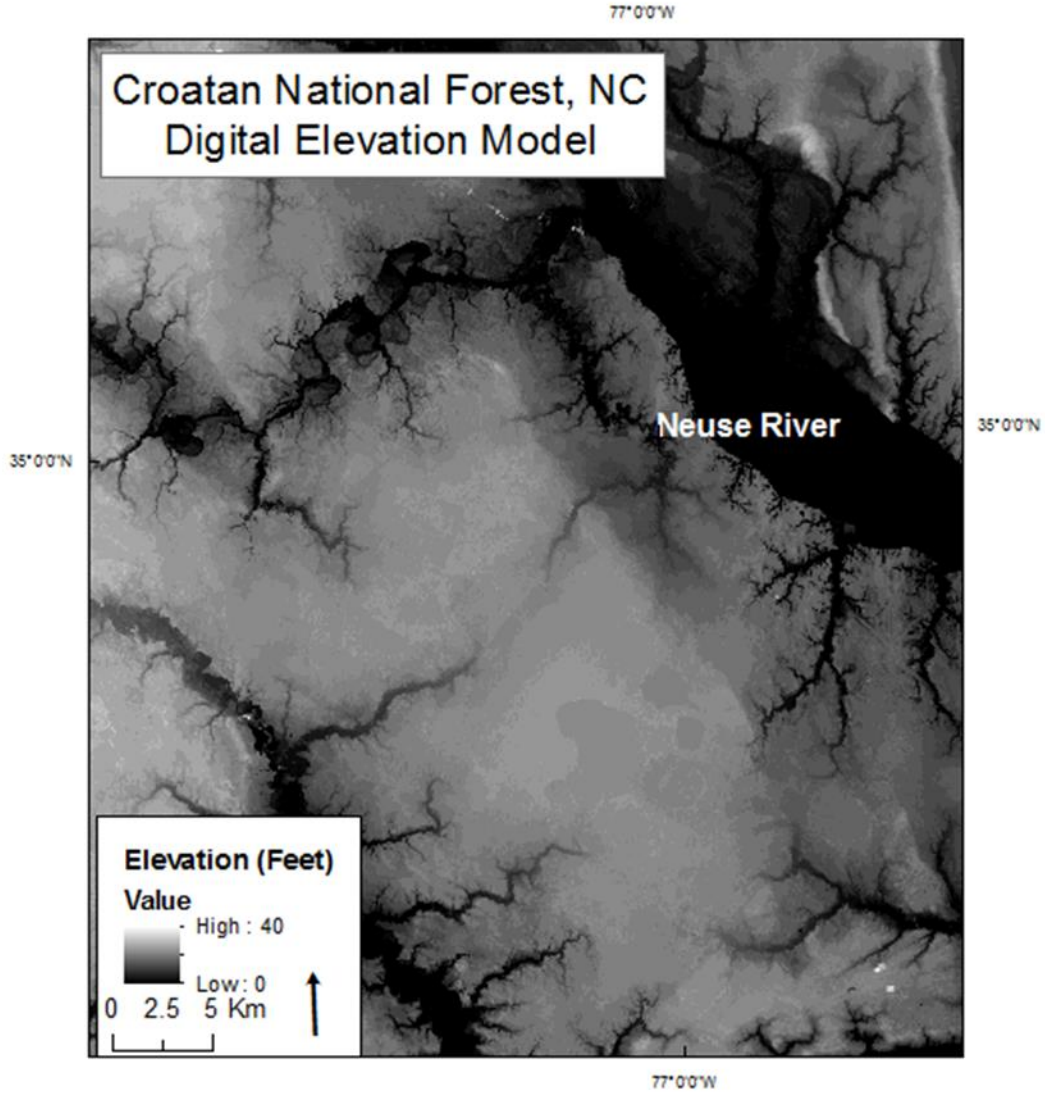

Figure 2: Digital elevation model of the CNF region. Note the high elevation of the center of the forest relative to the surrounding regions to which rivers drain.

Methods

Surface Water Samples

Samples were collected in bottles that had been thoroughly cleaned in MilliQ water and nitric acid to ensure that Sr from the bottles would not contaminate the samples. The samples were then filtered. Between each sample the filtering equipment was thoroughly rinsed in MilliQ water, vibrated in an ultrasound machine, and dried using compressed air. The samples were weighed, a known mass of a ^{84}Sr spike was added, then the samples were dried down, dissolved in a solution of 3.5N nitric acid, and centrifuged prior to isolation of Sr by column chromatography.

Precipitation

Twenty precipitation samples were sent from the University of North Carolina—Wilmington. At UNC-W, the samples had been collected in combusted glass beakers and filtered within 12 hours of cessation of precipitation through 0.2 micron pore size membrane filters. The samples were stored at 4 degrees Celsius in glassware that was thoroughly rinsed in MilliQ water and combusted to remove organic contaminants. The samples were shipped to the University of North Carolina—Chapel Hill in acid washed polyethylene bottles (Helms, personal communication 28 August 2013). An empty bottle was also included as a blank and showed that the bottles did not contaminate the precipitation samples. The samples were weighed, a known mass of a ^{84}Sr spike was added, then the samples were dried down, dissolved in a solution of 3.5N nitric acid, and centrifuged prior to isolation of Sr by column chromatography.

Surficial Wells

Water samples were collected from surficial wells maintained by the North Carolina Division of Water Resources. The wells sampled were at the Croatan U18O station and the

Clarks S22J5 station. On the date of sampling, the water level at the Croatan U180 station was 7.04 feet (2.15 m) below ground surface (elevation 18.8 feet [5.73 m]), and the water level at the Clarks S22J5 station was 21.17 feet (6.45 m) below ground surface (elevation 6.55 feet [1.00 m]) (Peck, personal communication 7 April 2014). Water was taken from the wells using a new bailer. The first time the bailer was filled, the water was discarded. Samples were collected after filling the bailer a second time. Samples were collected and stored in bottles that had been thoroughly cleaned with MilliQ water and nitric acid. The samples were then filtered. Between each sample the filtering equipment was thoroughly rinsed in MilliQ water, vibrated in an ultrasound machine, and dried using compressed air. The samples were weighed, a known mass of a ^{84}Sr spike was added, then the samples were dried down, dissolved in a solution of 3.5N nitric acid, and centrifuged prior to isolation of Sr by column chromatography.

Vegetation Samples

Tree branches approximately 1-1.5 cm in diameter were removed from trees using pruning shears. The bark was peeled from the branches. The remaining wood was cut into pieces and placed in ceramic crucibles which had been soaked in distilled water. The samples were weighed, placed in a drying oven overnight, cooled in a closed container with a desiccant to prevent reabsorption of water, and weighed again. The samples were then ashed in a muffle furnace using the following procedure: The furnace was initially set at 200ºC, and the temperature was increased by 50º every half hour (to prevent the samples catching fire and cross-contaminating due to smoking) until the furnace was 475ºC. The samples remained in the muffle furnace overnight.

The ashes were weighed, then dissolved overnight in a solution of 50% MilliQ water and 50% concentrated (13.5N) nitric acid. The samples were dried down and dissolved in a solution

of 3.5N nitric acid. A known mass of a ^{84}Sr spike was added, and the samples were centrifuged prior to isolation of Sr by column chromatography.

Separation of Sr was accomplished using Eichrom Sr specific resin for all the samples. The resin was fully rinsed in MilliQ water twice, then preconditioned using 500 microliters of 3.5N HNO_3. The samples were then loaded into the columns, and then rinsed with nitric acid using both dropwise and bulk sample rinse procedures. The samples were collected in new beakers by rinsing the columns twice with MilliQ water, and 1 drop of H_3PO_4 was added before the samples were dried down. The samples were re-dissolved in 2 microliters each of hydrochloric acid and tantalum chloride emitter solution prior to being dried onto single Re filaments for mass spectrometry. The samples were analyzed on a VG Sector 54 Thermal Ionization Mass Spectrometer housed in the Department of Geological Sciences at the University of North Carolina—Chapel Hill. Analysis of Sr was accomplished with a 3V ^{88}Sr ion beam on 10^{11} ohm resisters in triple dynamic mode. All data are normalized to $^{86}Sr/^{88}Sr = 0.1194$ assuming exponential fractionation behavior. Replicate analyses of the NBS-987 Sr standard yield $^{87}Sr/^{86}Sr = 0.710258 \pm 0.000014$.

Elevation

The Extract Values to Points tool in ArcMap was used to calculate the elevations of sample locations for surface water samples, using a digital elevation model and sample locations as inputs. The digital elevation model was acquired from the National Elevation Dataset produced by the United States Geological Survey. The data is from 2003 and has a resolution of 1/9 arc second (3 meters).

Results

The 2-σ absolute error for all $^{87}Sr/^{86}Sr$ ratios was calculated using the following equation:

2σ absolute error = ($^{87}Sr/^{86}Sr$ ratio)*(1σ % standard error)*(0.02)

Surface Water

The $^{87}Sr/^{86}Sr$ ratios for surface water samples are widely variable, with a range of 0.708611 ± 0.00001 - 0.710859 ± 0.00001 (Table 1). The highest $^{87}Sr/^{86}Sr$ ratios are found within the pocosin at elevations higher than 1.8 meters and in rivers that flow out of the pocosin (Figures 3-5).

Precipitation

Precipitation samples have $^{87}Sr/^{86}Sr$ ratios ranging from 0.708738 ± 0.00001 – 0.710630 ± 0.00001 (Table 2). The average $^{87}Sr/^{86}Sr$ ratio for precipitation samples is 0.709364. Codes for storm type are based on hind-cast positions of the air mass of the storm at three different heights in the 72 hours preceding the storm. Thus, terrestrial are storms in which the air mass primarily passed over terrestrial environments, marine are storms in which the air mass primarily passed over marine environments, and coastal are storms in which the air mass primarily passed over the coast (Helms, Personal communication 5 Oct. 2013). Mixed (category 1) refers to storms in which air masses at different heights have passed over different environments and the air masses are assumed to have mixed due to wind shear. Mixed (category 3) refers to storms in which the air masses at all heights have passed over both terrestrial and marine environments (Helms, Personal communication 12 Nov. 2013).

The plot of $^{87}Sr/^{86}Sr$ ratios and Sr concentrations in Figure 6 shows a possible mixing curve within the precipitation samples, with one end member characterized by an $^{87}Sr/^{86}Sr$ ratio of 0.708738 and a Sr concentration of 0.000794 ppm, and the other end member characterized by

Sample	[Sr] (ppm)	$^{87}Sr/^{86}Sr$ ratio	Error	Elevation (ft.)	Elevation (m.)
TR-Y	1.72	0.709179	0.00001	0	0
BC	1.69	0.709156	0.00004	2	0.61
NR	3.01	0.709171	0.00001	0	0
GL	0.0122	0.710156	0.000009	11	3.35
CF-L	0.00723	0.710149	0.00001	10	3.05
CF-C	0.00561	0.709931	0.000009	10	3.05
LR	0.0424	0.710840	0.00001	9	2.74
CB	0.0173	0.710859	0.00001	9	2.74
CF-C2	0.00853	0.710132	0.00001	7	2.13
CF-C1	0.0194	0.710831	0.00001	6	1.83
HC	0.0129	0.710348	0.00001	5	1.52
NF1	0.0196	0.709823	0.00001	4	1.22
NF2	0.0200	0.710638	0.00001	3	0.91
AR	0.0264	0.710043	0.000006	2	0.61
CL-1	0.0208	0.710240	0.00001	3	0.91
CP	0.104	0.709377	0.00001	0	0
GFH	0.0255	0.709897	0.000009	0	0
WO-H	0.155	0.708727	0.00001	3	0.91
WO-M	0.0383	0.708942	0.000009	1	0.3
WO-L	0.178	0.708611	0.00001	5	1.52
TR-P	0.0586	0.708758	0.00001	1	0.3
CL-2	0.0617	0.708801	0.000009	0	0
IC	0.0453	0.708983	0.00001	1	0.3

Table 1: Surface water sample concentrations, $^{87}Sr/^{86}Sr$ ratios, and elevations. $^{87}Sr/^{86}Sr$ ratios have a range of 0.708611 ± 0.00001 - 0.710859 ± 0.00001.

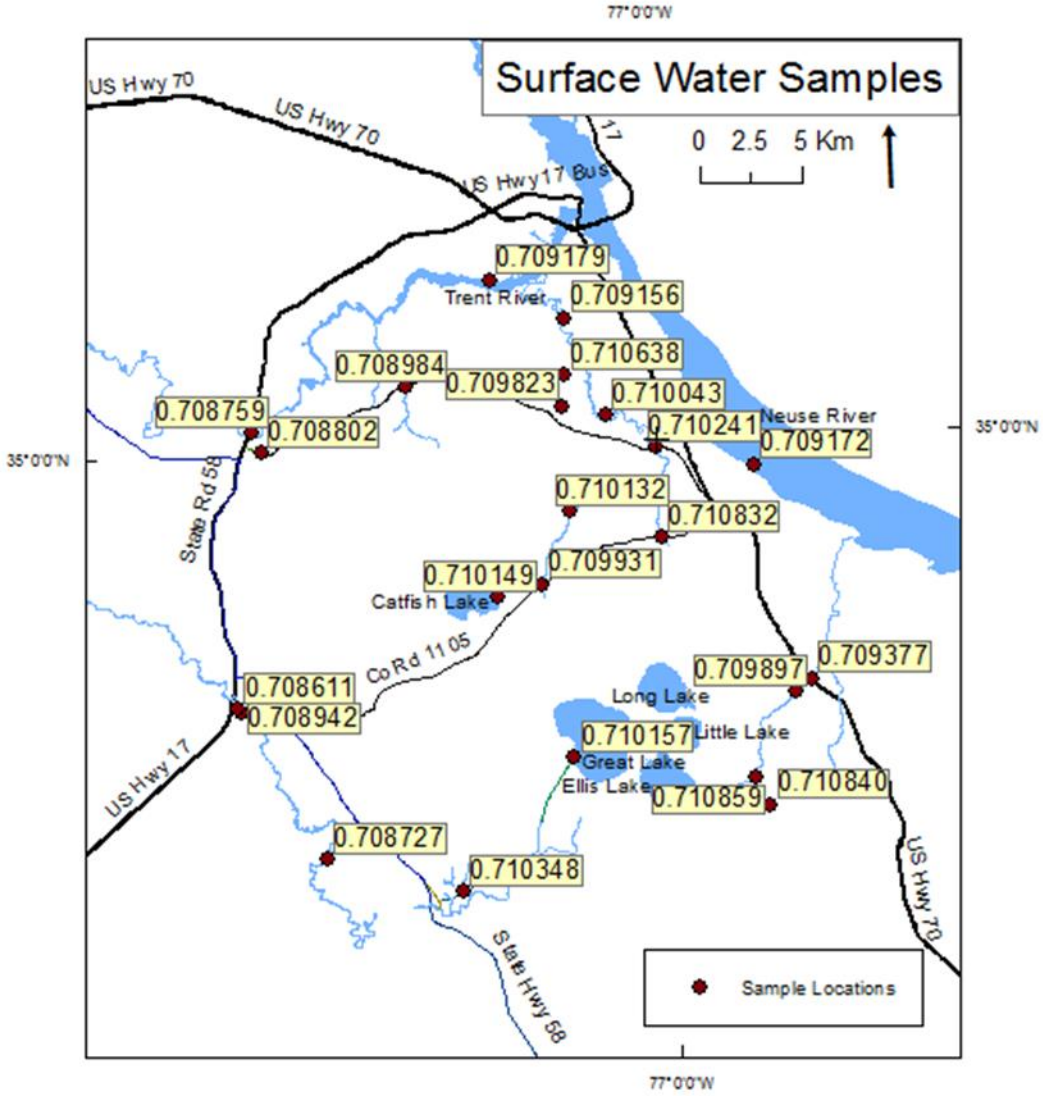

Figure 3: Map of $^{87}Sr/^{86}Sr$ ratios of surface water samples. Note that $^{87}Sr/^{86}Sr$ ratios are highest in the pocosin and in surface waters that flow radially out of the pocosin. On the Neuse River and the eastern Trent River, $^{87}Sr/^{86}Sr$ ratios are comparable to modern seawater. To the west of the CNF on the Trent River and White Oak River, $^{87}Sr/^{86}Sr$ ratios are within the ranges of $^{87}Sr/^{86}Sr$ ratios for groundwater (Woods et al, 2000) and Eocene to Miocene seawater (Burke et al, 1982).

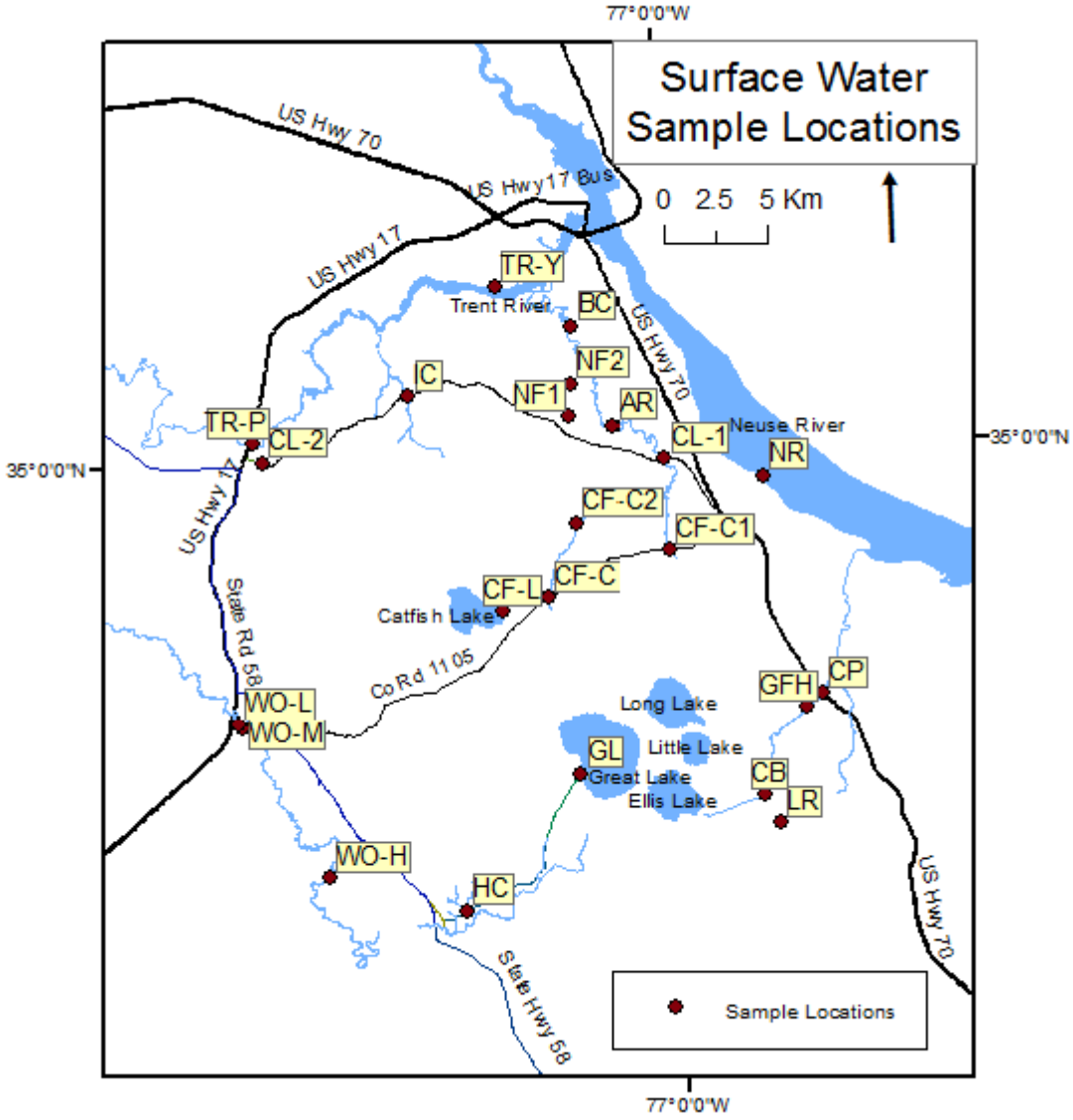

Figure 4: Map of surface water samples by sample name

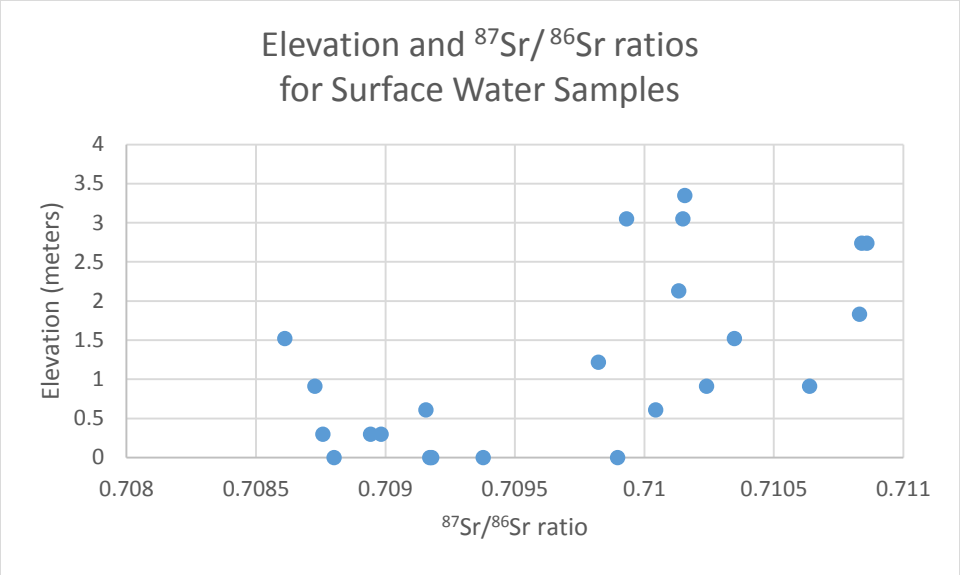

Figure 5: Scatter plot showing $^{87}Sr/^{86}Sr$ ratios vs. elevation for surface water samples. Samples at elevations higher than 1.8 meters, and rivers that flow out of the pocosin, have $^{87}Sr/^{86}Sr$ ratios higher than modern seawater. Samples with low $^{87}Sr/^{86}Sr$ ratios relative to modern seawater are only located at elevations lower than 1.8 meters.

Sample	[Sr] (ppm)	$^{87}Sr/^{86}Sr$ ratio (Series A)	Error	$^{87}Sr/^{86}Sr$ ratio (Series B)	Error	storm type
E1274	0.0163	0.709315	0.00001	0.709304	0.00001	3 mixed
E1276	0.00315	0.709406	0.00001			2 terrestrial
E1277	0.00238	0.709168	0.00001	0.7091738	0.00001	1 mixed
E1281	0.0113	0.709341	0.00001			1 mixed
E1285	0.00151	0.709032	0.00001			4 coastal
E1286	0.00138	0.709198	0.00001	0.7092228	0.00001	3 mixed
E1288	0.00504	0.709290	0.00001	0.7092755	0.000009	3 mixed
E1307	0.000794	0.708738	0.00001			5 marine
E1319	0.00128	0.710630	0.00001	0.7106791	0.00001	4 coastal
E1321	0.00133	0.709227	0.00001			5 marine
E1324	unavailable	unavailable		0.7097954	0.00001	5 marine
E1327	0.000732	0.708998	0.00001			3 mixed
E1332	unavailable	unavailable		0.7092819	0.00001	4 coastal
E1342	unavailable	unavailable		0.7096361	0.00001	4 coastal

Table 2: Results of Sr isotope geochemistry for precipitation samples. $^{87}Sr/^{86}Sr$ ratios range from 0.708738 ± 0.00001 – 0.710630 ± 0.00001. The average $^{87}Sr/^{86}Sr$ ratio is 0.709364. Series A are the samples from the first batch. Series B are the samples for which mass spectrometry was repeated, omitting the ^{87}Sr spike and drying down roughly eight times as much sample.

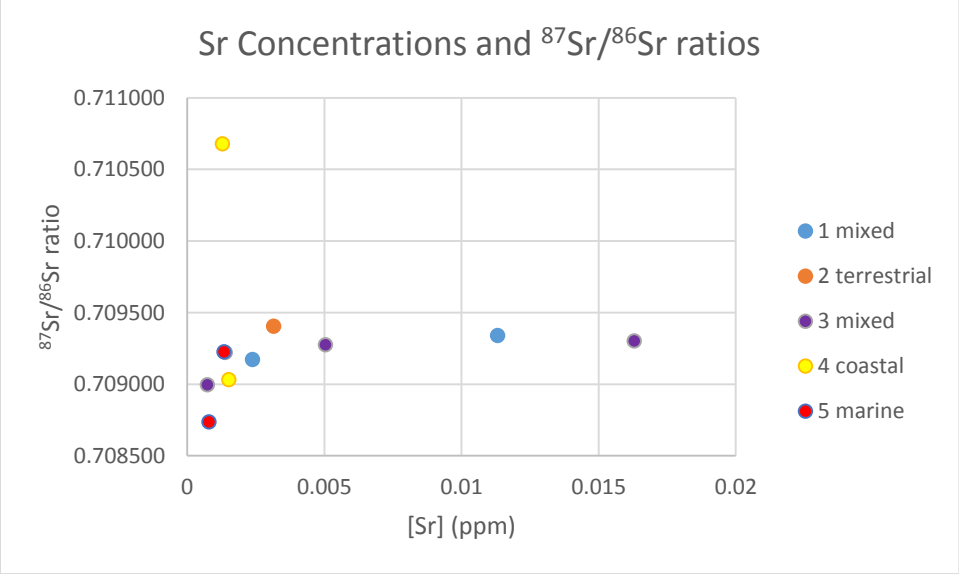

Figure 6: Plot of Sr concentrations vs. $^{87}Sr/^{86}Sr$ ratios, color-coded by storm type. Shows a possible mixing curve within the precipitation samples, with one end member characterized by an $^{87}Sr/^{86}Sr$ ratio of 0.708738 and a Sr concentration of 0.000794 ppm, and the other end member characterized by an $^{87}Sr/^{86}Sr$ ratio of 0.709315 and a Sr concentration of 0.0163 ppm.

an $^{87}Sr/^{86}Sr$ ratio of 0.709315 and a Sr concentration of 0.0163 ppm. No pattern is apparent when storm type is plotted against $^{87}Sr/^{86}Sr$ ratios (Figure 7) or Sr concentration (Figure 8).

Sr concentrations for the precipitation samples were very low; the mass spectrometer was unable to receive a signal for nine of the precipitation samples due to the low Sr concentrations. Because of the low concentrations, it was concluded that adding the ^{84}Sr spike could add possible error to the measured $^{87}Sr/^{86}Sr$ ratios. To test the accuracy of the results, mass spectrometry was repeated for eight of the samples, this time excluding the ^{84}Sr spike and drying down roughly eight times as much sample. (These samples are referred to as Series B.)

Wells

$^{87}Sr/^{86}Sr$ ratios of surficial wells are 0.709687 ± 0.00001 and 0.709415 ± 0.00001, within the range of $^{87}Sr/^{86}Sr$ ratios for surface water samples (Table 3, Figure 9).

Vegetation Samples

The $^{87}Sr/^{86}Sr$ ratios of vegetation samples are widely variable, with a range of 0.708125 ± 0.00001 - 0.712245 ± 0.00001 (Table 4, Figure 10).

Discussion

Precipitation

Within the pocosin of the Croatan National Forest, precipitation is expected to be the main source of water because of its high elevation relative to the surrounding area. The average $^{87}Sr/^{86}Sr$ ratio for the precipitation samples is 0.709364, significantly less radiogenic than the Sr of the peat. Strontium concentrations in precipitation are also generally lower than Sr concentrations of surface water samples. Since $^{87}Sr/^{86}Sr$ ratios for precipitation are on average lower than the high ratios found in surface waters and the peat samples of Sun (2012), it is unlikely that precipitation is the source of high $^{87}Sr/^{86}Sr$ ratios. The Sr chemistry in the surface

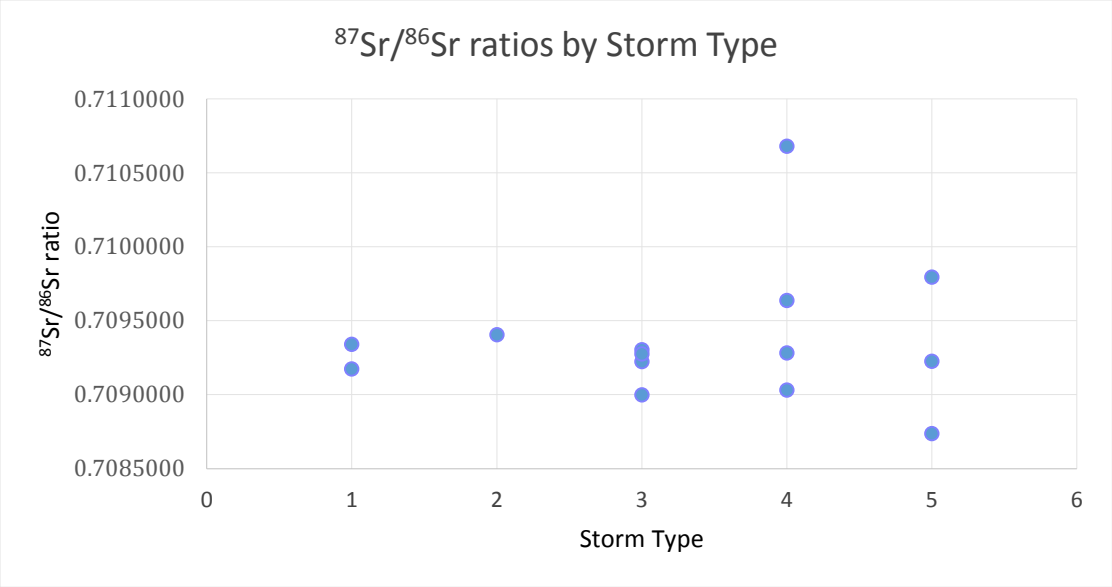

Figure 7: Plot of $^{87}Sr/^{86}Sr$ ratios for each storm type (using codes shown in Figure 6). No pattern is apparent.

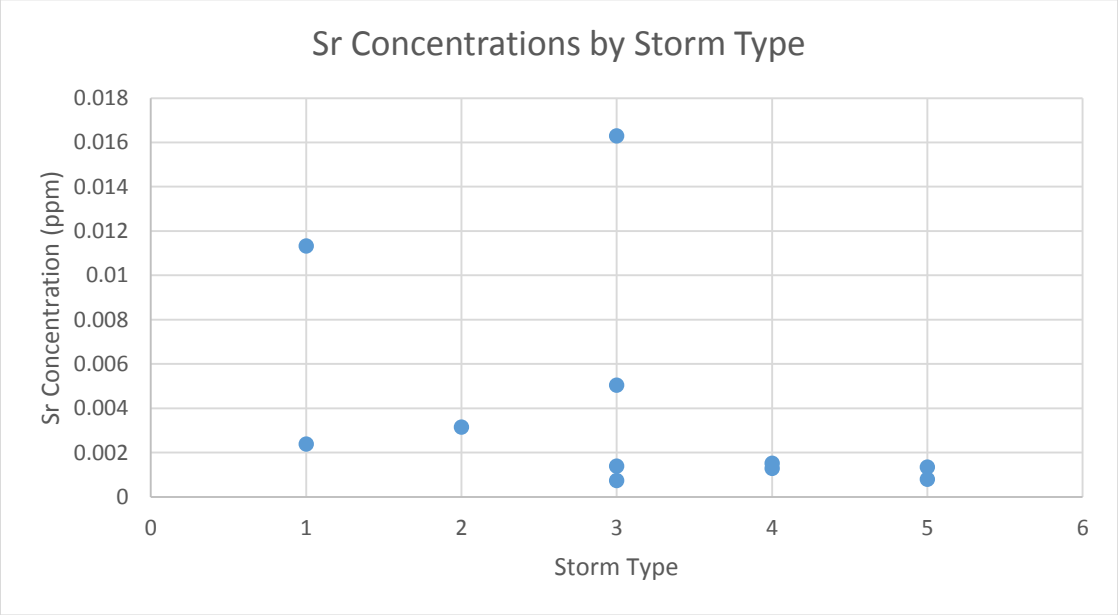

Figure 8: Plot of Sr concentrations for each storm type (using codes shown in Figure 6). No pattern is apparent.

Well	[Sr] (ppm)	$^{87}Sr/^{86}Sr$ ratio	Error
Croatan U180	0.102	0.709687	0.00001
Clarks S22J5	0.515	0.709415	0.00001

Table 3: Sr concentrations and $^{87}Sr/^{86}Sr$ ratios for well samples. Note that $^{87}Sr/^{86}Sr$ ratios are higher than modern seawater and within the range of $^{87}Sr/^{86}Sr$ ratios seen in surface waters in the pocosin; however, $^{87}Sr/^{86}Sr$ ratios of well samples are not as high as $^{87}Sr/^{86}Sr$ ratios of peat in the pocosin.

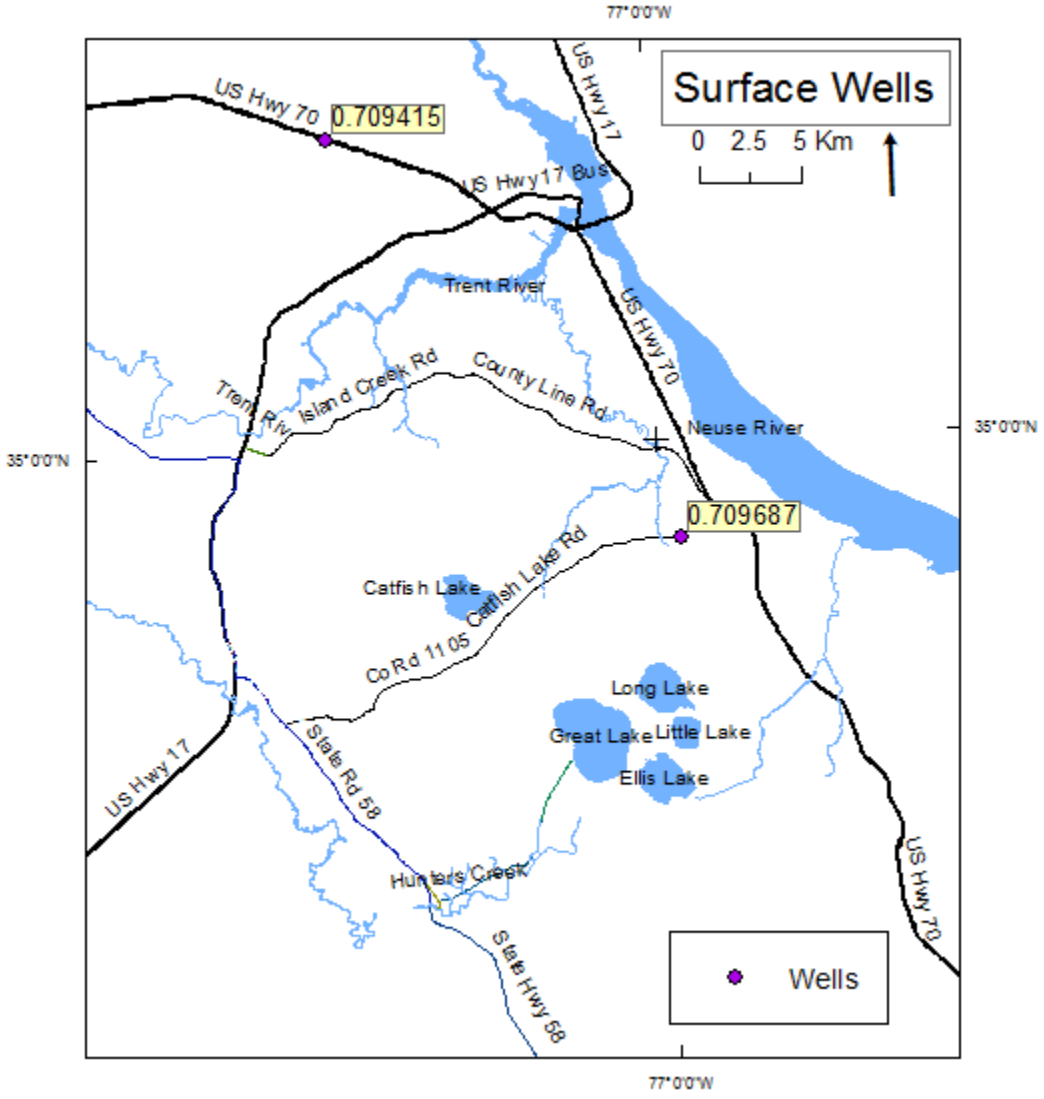

Figure 9: Map of $^{87}Sr/^{86}Sr$ ratios of surface well samples.

Sample	[Sr] (ppm)	$^{87}Sr/^{86}Sr$ ratio	Error
V1	2.63	0.709097	0.00001
V2	4.49	0.710525	0.00001
V3	7.12	0.712245	0.00001
V4	3.64	0.710435	0.00001
V5	20.8	0.708835	0.00001
V7	5.11	0.708174	0.00001
V8	3.30	0.709380	0.002
V9	2.77	0.708125	0.00001
V10	4.60	0.709362	0.00001
V11	4.89	0.708445	0.00001

Table 4: Sr concentrations and $^{87}Sr/^{86}Sr$ ratios for vegetation samples. The range of $^{87}Sr/^{86}Sr$ ratios is 0.708125 ± 0.00001-0.712245 ± 0.00001.

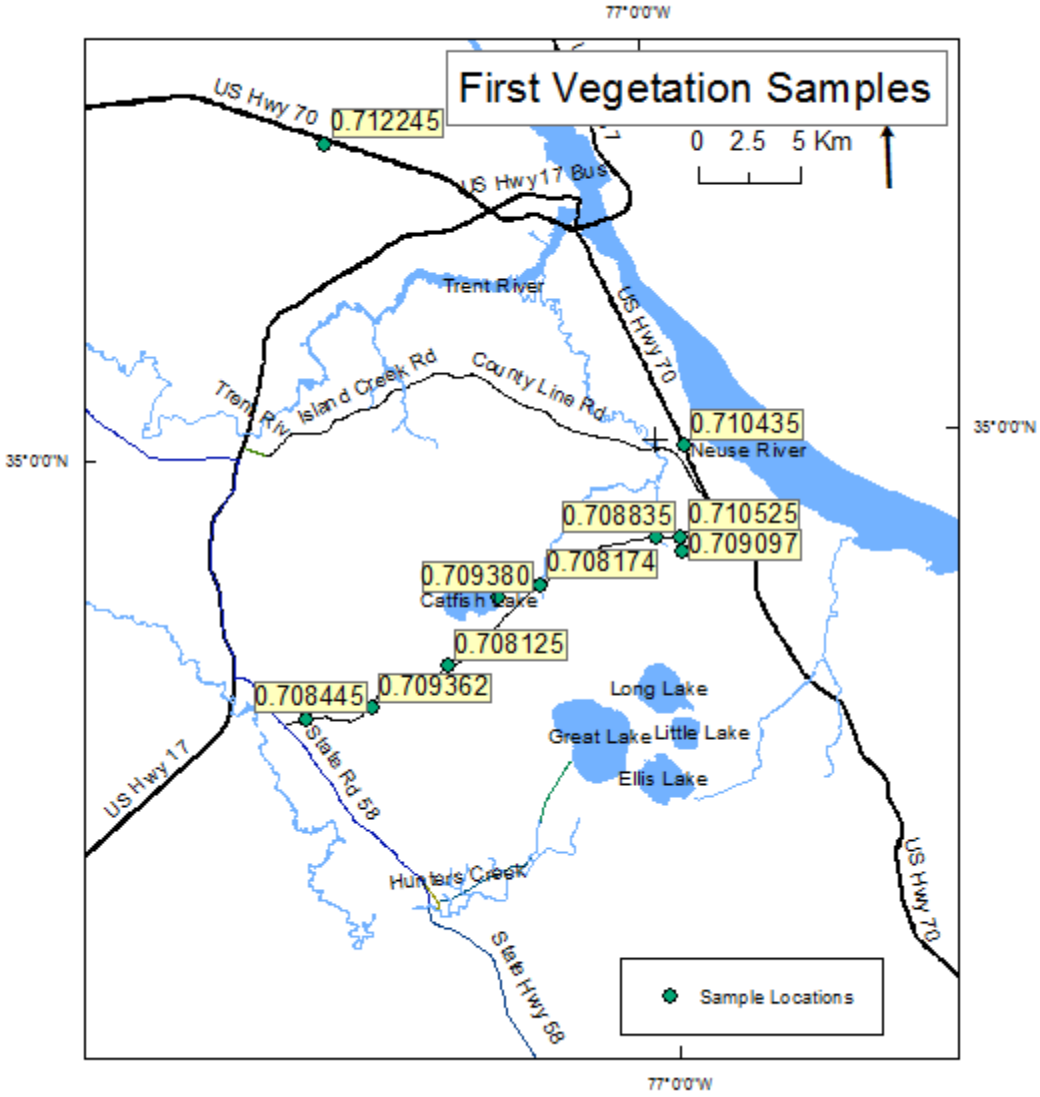

Figure 10: Map of $^{87}Sr/^{86}Sr$ ratios of vegetation samples. No geographical pattern is apparent. Vegetation samples also do not have the same $^{87}Sr/^{86}Sr$ ratios as nearby surface waters.

waters of the pocosin therefore reflects mixing between precipitation and other sources such as the peat sampled by Sun (2012) as it drains to rivers and lakes.

Precipitation sample E1274 has the highest Sr concentration (0.0163 ppm) of all the precipitation samples, and its $^{87}Sr/^{86}Sr$ ratio is 0.709315 ± 0.00001. Figure 11, which depicts the effects of mixing sample E1274 with three rivers from the CNF region (based on $^{87}Sr/^{86}Sr$ ratios of samples BC, NF-1, and HC), shows that even replacing 20% of the river volume with precipitation has little effect on the $^{87}Sr/^{86}Sr$ ratio of the rivers. Because the Sr concentration in precipitation is low relative to Sr concentrations in surface waters, and the volume of precipitation relative to the volume of water in rivers is small, $^{87}Sr/^{86}Sr$ ratios in surface waters are not expected to be affected significantly by individual precipitation events.

Pocosin Surface Waters

Water samples collected from elevations higher than 1.8 meters have $^{87}Sr/^{86}Sr$ ratios higher than modern seawater. Samples collected from rivers that are at lower elevations but flow out of the pocosin also have $^{87}Sr/^{86}Sr$ ratios higher than modern seawater. The surface waters from which these samples were collected appear to be mixing with a source of high $^{87}Sr/^{86}Sr$ ratios.

Surface Waters at Lower Elevations

The Neuse River has an $^{87}Sr/^{86}Sr$ ratio of 0.709171 ± 0.00001, within error of modern seawater. This is to be expected because the Neuse River in the CNF region is estuarine and mixes with the Atlantic Ocean. The Sr concentration of sample NR is 3.01 ppm. Sample TR-Y, collected near the confluence of the Trent River and the Neuse River, has an $^{87}Sr/^{86}Sr$ ratio of

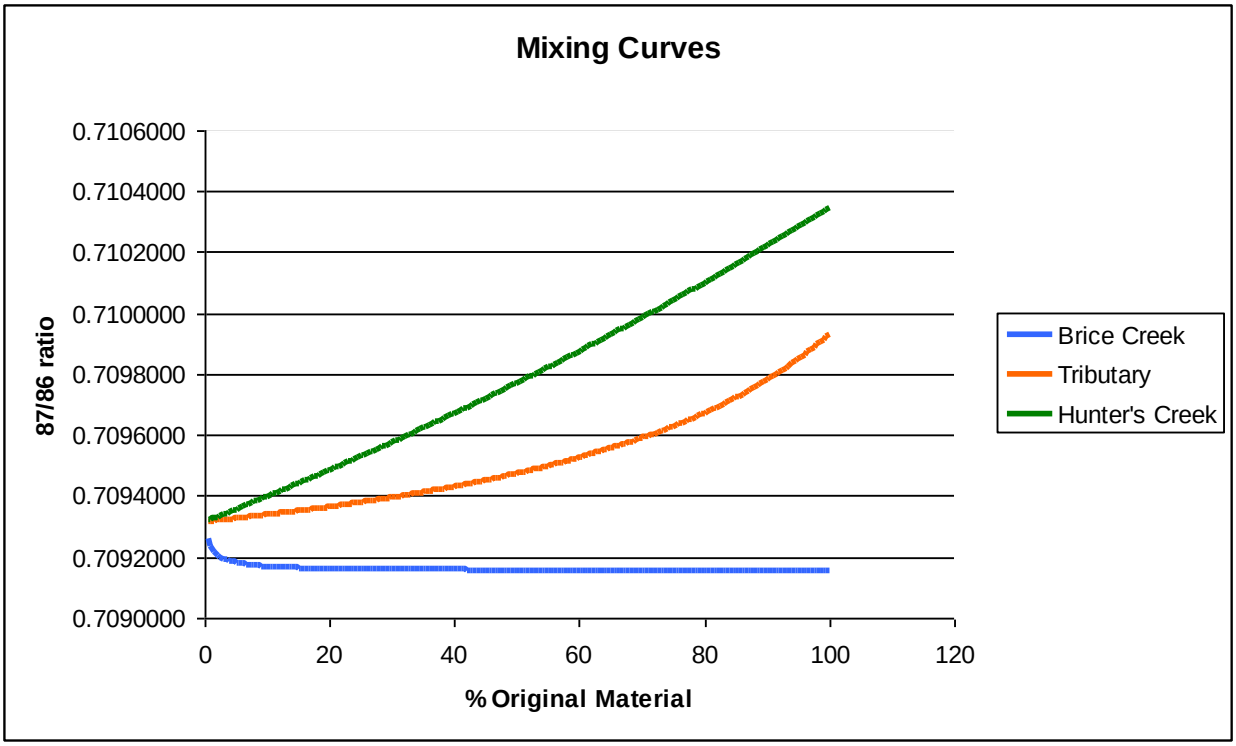

Figure 11: Mixing curves showing the effects of mixing precipitation sample E1274 with Brice Creek, a tributary of Brice Creek, and Hunter's Creek. 100% original material would consist entirely of water from the river, whereas 0% original material would consist entirely of precipitation sample E1274. These mixing curves indicate that a single precipitation event is unlikely to significantly affect the $^{87}Sr/^{86}Sr$ ratios of surface waters.

The mixing curves in Figure 11 were calculated using mixing equations from Faure (2005):

$$X_M = X_A f_A + X_B(1-f_A)$$

Eq. 16.4

X_M=*Concentration of Sr in mixture*
X_A=*Concentration of Sr in A*
X_B=*Concentration of Sr in B*
f_A=*abundance of A in mixture*

$$(^{87}Sr/^{86}Sr)_M = (^{87}Sr/^{86}Sr)_A\ (f_A)\ (Sr_A/Sr_M) + (^{87}Sr/^{86}Sr)_B\ (1-f_A)\ (Sr_B/Sr_M)$$

Eq. 16.11

Sr_A=*Concentration of Sr in A*
Sr_B=*Concentration of Sr in B*
Sr_M=*Concentration of Sr in the mixture*

0.709179 ± 0.00001, within error of modern seawater. The Sr concentration of sample TR-Y is 1.72 ppm.

Based on a plot of $^{87}Sr/^{86}Sr$ ratios and concentrations on Brice Creek (Figure 12), which flows north out of the pocosin and ultimately drains into the Trent River, it appears that the Trent River and the Neuse River are not mixing significantly with rivers flowing out of the pocosin of the CNF. Only sample BC, the sample on Brice Creek collected closest to the Trent River, has a Sr concentration and $^{87}Sr/^{86}Sr$ ratio comparable to the Trent River and the Neuse River. The other samples on Brice Creek are characterized by low Sr concentrations (less than 0.0264 ppm) and $^{87}Sr/^{86}Sr$ ratios greater than 0.709823.

Samples collected from the Trent River and White Oak River west of the CNF have $^{87}Sr/^{86}Sr$ ratios of 0.708611 ± 0.000009 – 0.708758 ± 0.00001. These ratios are comparable to groundwater (0.708104-0.709006) as measured by Woods et al. (2000). These ratios also fall within the range of $^{87}Sr/^{86}Sr$ ratios estimated to be found in seawater during the late Eocene to early Miocene epochs, which are 0.7076-0.7089 (Burke et al, 1982).

Figure 5 shows that $^{87}Sr/^{86}Sr$ ratios of surface waters in the CNF region are not a function of elevation. However, elevation does impact flow paths of water, which inhibits water at higher elevations mixing with the Neuse, Trent, and White Oak Rivers. Thus, $^{87}Sr/^{86}Sr$ ratios at elevations above 1.8 meters are higher than modern seawater, and high $^{87}Sr/^{86}Sr$ ratios at low elevations occur in rivers that flow out of the pocosin. $^{87}Sr/^{86}Sr$ ratios lower than modern seawater only occur at elevations below 1.8 meters.

Wells

The $^{87}Sr/^{86}Sr$ ratios of the surficial well water samples are higher than modern seawater and comparable to $^{87}Sr/^{86}Sr$ ratios of surface water samples within the CNF where little mixing

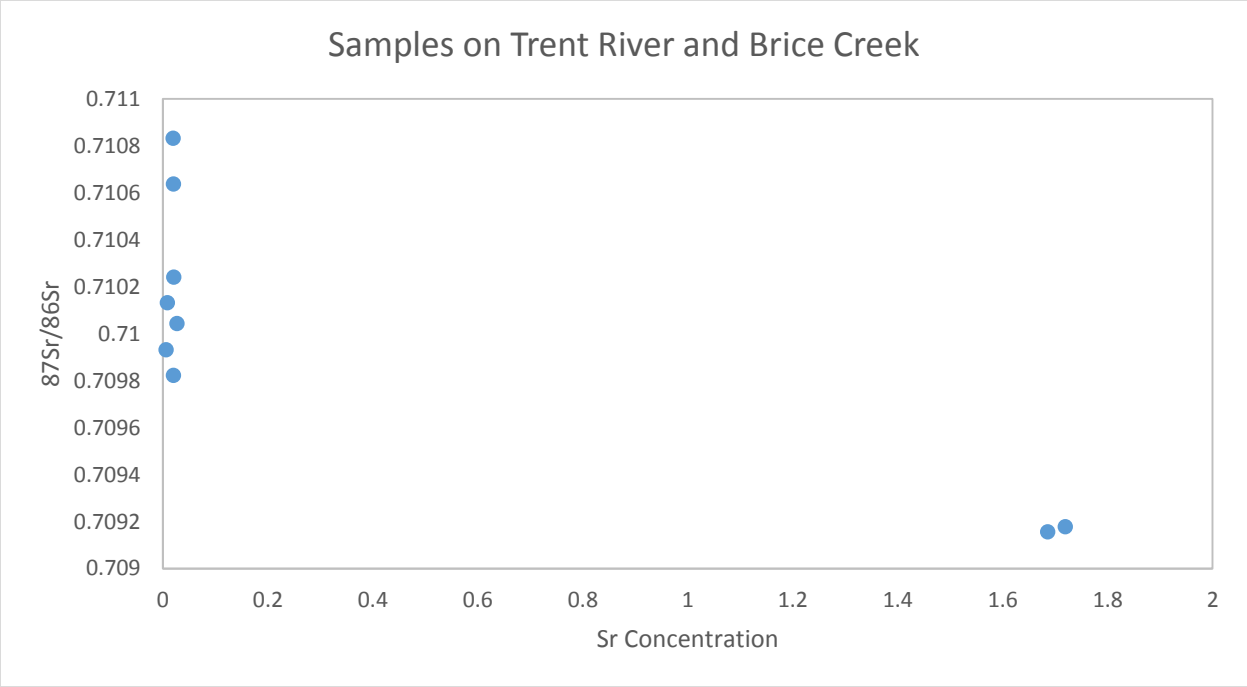

Figure 12: Sr concentration and $^{87}Sr/^{86}Sr$ ratios of sample TR-Y and samples collected along Brice Creek. It is apparent based on this plot that with the exception of sample BC (Sr concentration 1.69 ppm and $^{87}Sr/^{86}Sr$ ratio 0.709156), collected near the confluence of Brice Creek and the Trent River, little mixing is occurring between Brice Creek and the Trent River.

with the Neuse and Trent Rivers has occurred. However, many surface water samples have higher $^{87}Sr/^{86}Sr$ ratios than the well water samples. Samples of wells in the region northeast of the CNF have $^{87}Sr/^{86}Sr$ ratios of 0.708104-0.709006 (Woods et al, 2000). This indicates that groundwater from these sources is not the cause of high $^{87}Sr/^{86}Sr$ ratios in the CNF; however, like the surface water, groundwater does mix or come in contact with a source of high $^{87}Sr/^{86}Sr$ ratios.

Vegetation

The results for vegetation samples are inconclusive. No spatial patterns are apparent when $^{87}Sr/^{86}Sr$ ratios are plotted at sampling locations, and vegetation samples do not have the same $^{87}Sr/^{86}Sr$ ratios as nearby surface waters. One possible explanation is that vegetation samples were collected from several varieties of trees. Different species of trees may sample Sr at different depths in the soil. In future studies, vegetation samples should be collected again from the same tree species to determine if geographical patterns are apparent in vegetation.

Sources of High $^{87}Sr/^{86}Sr$ Ratios

None of the surface water, well water, precipitation, or vegetation samples have had $^{87}Sr/^{86}Sr$ ratios as high as those found in the peat in Sun's study. The source of high $^{87}Sr/^{86}Sr$ ratios is as yet undetermined. This source may be atmospheric dust. This hypothesis could be tested by analyzing the Sr chemistry of tree bark. Bulleri (2003) concludes that tree bark can be used to monitor airborne contaminants. The source of high $^{87}Sr/^{86}Sr$ ratios may also be upwelling of deep groundwater that has come in contact with basement rocks. This hypothesis could be tested by sampling from deeper wells.

Conclusion

Samples from surface waters and surficial wells in the pocosin of the Croatan National

Forest have $^{87}Sr/^{86}Sr$ ratios higher than modern seawater. Precipitation has a lower average $^{87}Sr/^{86}Sr$ ratio than surface waters and therefore cannot be the source of high $^{87}Sr/^{86}Sr$ ratios to the region. We conclude that there is an unknown source of high $^{87}Sr/^{86}Sr$ ratios interacting with the forest. This source may be atmospheric dust or upwelling of deep groundwater that has been in contact with the basement rocks below the forest.

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Acknowledgements

John Helms sent the precipitation samples from UNC-Wilmington. Barbara Peck from the North Carolina Division of Water Resources arranged and assisted with the sampling of the wells. Many thanks to Drew Coleman and Larry Benninger, who gave advising for the methods and interpretations of results throughout this study.